View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by Digital Repository @ Iowa State University

(298)

Non-Contact Evaluation of Residual Stress in Metals with Laser-Generated Surface Acoustic Waves and a Point-Like Fiber-Optic Sagnac Detector

Łukasz Ambrozinski[1,2], **Ivan Pelivanov**[1], Michael B. Prime[3] and Matthew O'Donnell[1], [1]Department of Bioengineering, University of Washington, Seattle, WA/USA, 98105;
[2]AGH University of Science and Technology, 30-059 Krakow, Poland; [3]Los Alamos National Laboratory, Los Alamos, NM

Stress can remain in a material after the original load is removed. It can be purposely introduced to improve the properties of structural components, but can also be undesired, shortening a component's lifetime, changing its original geometry or even leading to failure.

There is a large spectrum of problems where residual stress must be evaluated. An acousto-elastic approach is non-destructive and uses stress-dependent alterations in ultrasound (US) speed of bulk or surface modes [1]. However, these alterations are incredibly small (10-3 ÷ 10-5) and, thus, accurate measurement of both the US wave speed and propagation distance is required. Thickness measurement is not required for surface acoustic waves (SW) as compared to bulk acoustic modes. However, it requires a well determined distance between source and detector and very accurate time-of-flight measurement.

Here we show that an approach based on laser-generated SW can solve this problem when a highly sensitive, point-like optical detector [2, 3] is used on receive. Using a laser beam focused to a narrow strip about 100 µm wide as a wave source and a modified Sagnac interferometer [2, 3] with an 8 µm diameter beam on receive, it is possible to use a short propagation path (5-10 mm) to obtain the required accuracy of time-of-flight measurements. For instance, the relative wave speed was estimated with an error of approx. 0.025% (i.e. $2.5 \cdot 10^{-4}$) when only 20 signal averages were applied. The in-plane distribution of relative deviations of SW speed (proportional to stress) can be obtained with 2D scanning over a sample [4]. An example of relative SW speed deviations in one cross-section is shown in Fig.1 for a stainless steel sample.

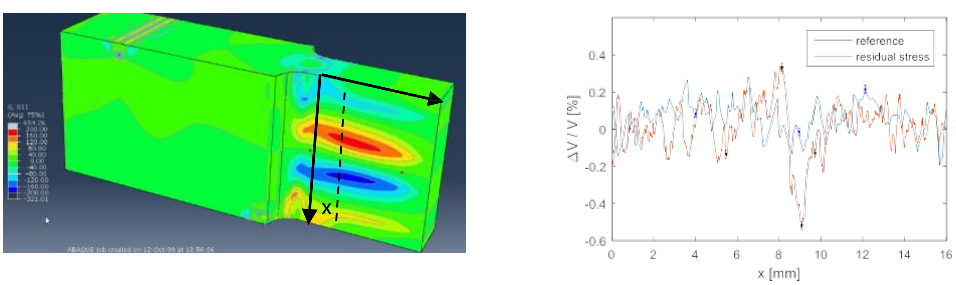

Figure 1. Simulated distribution of residual stress (left); comparison of relative deviations in the SW speed obtained experimentally for the reference sample and the sample with introduced residual stress (right).

References:

1. Guz A.N et al, "Introduction in acoustoelasticity," *Naukova Dumka, Kiev*, 152p. (1977).
2. Pelivanov I. et al, *J. Appl. Phys*. **115**(11), 113105-1-11 (2014).
3. Pelivanov I. et al, *Photoacoustics* **2**(2), 63-74 (2014).
4. Pelivanov I. et al, *IEEE Tran. UFFC* **62**(9), 1696-1703 (2015).